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New Evidence on Trade Liberalization and Productivity Growth*

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Abstract

Although the subject of a large number of studies, the debate on the links between trade reform and productivity growth is still unresolved and most studies at the micro level have not been able to establish a relationship between the two phenomena. Brazil provides a natural experiment to study this issue that is seldom available: it was one of the closest economies in the world until 1988, when trade reform was launched, and intra-industry data are available on an annual basis before, during and after liberalization. Using a panel of industry sectors this paper tests and measures the impact of trade reform on productivity growth. Results confirm the association between the former and the latter and show that the magnitude of the impact of tariff reduction on the growth rates of TFP and output per worker was substantial. Our data reveal large and widespread productivity improvement, so that the estimations in this paper are an indication that liberalization had an important effect on industrial performance in the country. Cross-sectional differences in protection are also investigated.

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1 Introduction

Economists continue to puzzle over the elusive nature of the relationship between productivity and trade reform. Results are at best ambiguous and, if any, only modest gains are predicted. For instance, in surveying the applied general equilibrium literature Kehoe and Kehoe(1994) write that the estimated effect of NAFTA is negligible for the US and Canada, and only worth 2.2 percent of GDP for Mexico. Tybout, de Melo and Corbo(1991) found no evidence of overall productivity improvement in the Chilean manufacturing sector after trade liberalization. Results in Tybout and Westbrook(1995) for the Mexican manufacturing sector are similar but the evidence is even weaker for trade liberalization affecting productivity. In a similar tone, Pack(1988) states that

> Comparisons of total factor productivity growth among countries pursuing different international trade orientations do not reveal systematic differences in productivity growth in manufacturing nor do the time-series studies of individual countries that have experienced alternating trade regimes allow strong conclusions in this dimension.

In fact, very few studies at the micro level have been able to present some evidence linking trade reform and increased productivity growth (two exceptions are Harrison(1994), that works with plant level data from Cote D'Ivoire, and Lee(1996) dealing with Korean industrial data at the 4-digit level). On the other hand, the evidence that trade protection mechanisms, such as tariffs and import restrictions, decrease growth rates of labor productivity (and some cases total factor productivity), obtained from studies that rely on cross-country regressions (e.g., Edwards(1993) and Ben-David[1993]) has been attacked recently by Rodríguez and Rodrik(1999) and Rodrik(1999). Their criticism is centered on methodological issues but could be interpreted as a rejection of the recent policy consensus on the beneficial impacts of openness.

However, as stated by Srinivasan and Bhagwati (1999), cross-countries regressions are not in any event the best tools for analyzing the problem of understanding the linkage between trade and growth, because of institutional and country-specific factors that are difficult to control. Moreover, when studying country experiences the important question to answer is what would have happened if a country had not adopted less restrictive trade policies. One empirical approach to deal with this question is to use data from the same country before and after a policy change.

In 1988, Brazil started a drastic process of trade liberalization that lasted until the early nineties. Monthly industrial surveys collected data before, during and after this process, providing a natural experiment. Data are available not only for the entire period but also for different industries of the manufacturing sector, also allowing the study of intra-industry effects of the reforms. The objective of this paper is to investigate the evidence that has emerged regarding the relationship of trade policy reform and productivity growth.

The case in point is especially interesting for the study of the links between trade and growth because Brazil was, until the nineties, one of the closest economies in the world[1], so that the gains from liberalization are potentially large if they exist. Moreover, unlike most studies such as those surveyed in Pack(1988), Harrison(1995) and Lee(1996) this paper works with "before and after " data. Hence, we have an experiment in which institutional and country factors are controlled, the data span stretches from five years before the policy change to some years later and the manufacturing industries included in the exercises comprise more than 90% of the total sector production.

Unlike most of the previous literature, we found strong evidence linking trade liberalization and productivity growth. Our data shows that after declining over the 1980s, both output per worker and total factor productivity (TFP) increased after trade liberalization. For example, TFP for 16 industries at two-digit level declined at an average annual rate of 1.01 percent from 1985 to 1989, but from 1994 to 1997 increased at an average annual rate of four percent. The figures for output per worker are similar, while 10 of those 16 industries had negative growth from 1985 to 1990 all but one grew at annual rates above 5% from 1991 to 1997. In the same period, average nominal tariffs for the manufacturing sector dropped from more than 100% to less than 15%, while the effective rate of protection declined to less than one fifth of its original level. The relationship between these phenomena is investigated econometrically in the paper, using panel techniques. Results confirm the linkages between trade reform and productivity growth and show that the magnitude of the impact of tariff reduction on the growth rates of TFP and output per worker was substantial.

This article relates to the literature of political and institutional barriers to growth (e.g., Holmes and Schmitz(1995), Parente and Prescott(2000)). In these studies, sectors with some degree of monopoly power over the supply

[1] In fact, it had in the seventies the fifth smallest trade share of all countries in the Summers and Helston database.

of specific factors can impose prices and block adoption of new technology. In Parente and Prescott (1999), for instance, a coalition of factor suppliers that is the monopoly seller of its input services can dictate work practices and member's wages. The monopoly right is protected by law, which makes it costly to enter the market with more productive technology. A corollary is that barriers to trade such as tariffs, quotas or any non-tariff barriers imposed by those interest groups affect the country's total factor productivity (TFP) level and growth prospects. If these barriers are destroyed the resistance to new technologies or new work practices is reduced, accelerating productivity growth. That is exactly what is shown in this paper, as barriers to trade were drastically reduced, industrial productivity soared while employment and hours experienced a substantial reduction.

The paper is organized in 4 sections, in addition to this introduction. The next section presents trade reform stylized facts while Section 3 discusses the evolution of labor productivity and TFP in the manufacturing sector in the period. Section 4 tests the link between productivity and trade restrictions while at the same time estimating productivity elasticity with respect to measures of trade protection. Section 5 concludes.

2 Trade Policy

Import substitution and protection of infant industries were the foundation of industrial policy and development strategy in Brazil (and Latin America as a whole) until the end of the eighties. Up to 1979, quantitative controls, reserved market shares and outright import bans were the dominant policy instruments. The so-called "lei do similar nacional" ("law of similar domestic production") banned the importation of or imposed prohibitive tariffs on any industrial product competing with domestic production. After 1979, tariffs were re-established as the main instrument of trade policy and quantitative controls were mostly abandoned gradually. However, to compensate for the decrease in industrial protection, nominal tariffs were raised to levels well above international standards. In 1988, a trade liberalization process began. This was rather timid, with the elimination of redundant tariffs, but after 1990 the pace of reform accelerated. All quantitative controls were definitively eliminated and a timetable was established for tariff reduction.

Table 1 displays the average nominal tariff for the 16 industries between 1987 and 1997[2].

[2]The nominal tariff and effective rate of protection data are from Pinheiro and Almeida (1994) and Kume(1996). 1997 data were based on the Mercosul common

Table 1: Average Nominal Tariffs

Industry	year		
	1987	1990	1997
Nonmetal mineral products	98.7	24.5	7.30
Metalworking	72.8	23.7	12.80
Machinery	62.1	39.5	13.90
Electronic and communication equipment	100.4	39.6	14.55
Transportation and motor vehicles	115.9	55.9	16.70
Paper and paper products	82.2	23.1	11.90
Rubber products	101.7	49.6	12.80
Chemicals	34.2	13.4	8.23
Pharmaceuticals	42.2	26	10.00
Perfumes, soap and candles	184.4	59.2	10.00
Plastic products	164.3	40	16.50
Textiles	161.6	38.8	15.80
Clothing, fabric products and footwear	192.2	50	19.60
Food	84.2	27.4	12.15
Beverages	183.3	75.1	14.50
Tobacco	204.7	79.6	9.00
average	117.81	41.59	12.86
Standard Deviation	56.01	19.02	3.40
max/min	5.99	5.94	2.68

On average, pre-reform tariffs were almost ten times larger than in 1997. The highest tariffs were observed in consumption industries such as tobacco, beverages and textiles. The lowest tariffs were those on intermediate industries such as chemical and machinery. Three years after the beginning of liberalization, tariffs were already only one-third of 1987 figures and dispersion (e.g., as measured by the ratio of standard deviation to average tariff) was also significantly reduced. This process went on until 1996, when dispersion was further reduced and the highest average tariff, on the clothing industry, was only 19%.

It is interesting to note that although the fall in nominal tariffs after trade liberalization is widespread across sectors, the ordering is more or less the same as before, and consumption industries still have more protection than intermediate and capital-goods industries. Another point worth mentioning is that, due to exceptions in the Mercosul agreement, protection of some specific sub-sector, as for instance the automobile, computers and freezers,

tariffs.

is still relatively high (e.g., more than 40% in the case of most automobiles) and in certain cases well above figures in Table 1.

The study of effective rates of protection behavior rather than nominal tariff behavior is certainly more important to understand the impact of trade policy on productivity growth. This is so because that measure takes into account not only the price of final products but also that of the inputs used in their production, and in principle it includes the effect of all of the factors that drive a wedge between world and domestic prices. Table 2 displays industry averages of the effective rate of protection[3] for the 1985-1997 period.

Table 2: Effective Rates of Protection

Industry	Year		
	1987	1990	1997
Nonmetal mineral products	31,5	42,2	14,5
Metalworking	59,8	34,5	17,5
Machinery	18,5	41,2	14,3
Electronic and communication equipment	108,2	53,3	16,7
Transportation and motor vehicles	43,5	178,2	33,8
Paper and paper products	31,0	22,8	12,6
Rubber products	125,0	67,1	14,7
Chemicals	64,9	21,5	10,3
Pharmaceuticals	52,3	36,3	9,9
Perfumes, soap and candles	96,1	76,0	26,1
Plastic products	427,7	54,2	22,3
Textiles	53,1	50,1	21,5
Clothing, fabric products and footwear	240,7	65,4	22,6
Food	32,7	33,5	15,7
Beverages	-7,6	93,0	19,9
Tobacco	-4,6	3,1	10,8
average	85,8	54,5	17,7
D.P.	105,6	38,5	6,2
max-min	435,3	175,1	23,9

Effective rate of protection felt in all industries but beverage and tobacco. On average, today's values are one-fourth of those of 1987. The decrease, however, is not uniform, and at least in the transportation industry the effective protection rate is still high. The largest reductions were observed

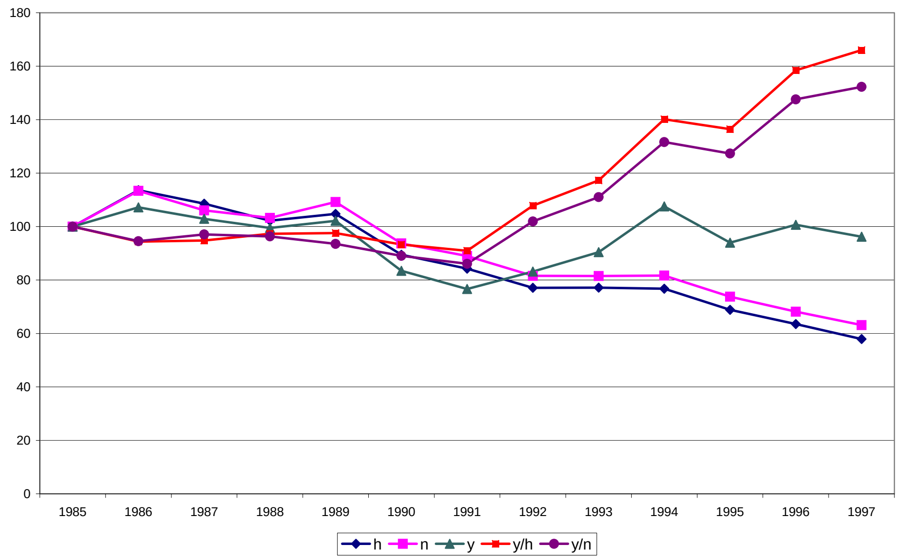
[3]See the appendix for more information on the data used in the paper.

in the plastic products industry and in the clothing, fabric products and footwear industry. In the first case, the current rate is less then 6% of its 85-89 average. Note also that there is a large decrease in the tariff dispersion: the standard error to average ratio fell from 1.23 to 0.35 in the period.

3 Productivity growth

3.1 Labor productivity

We had a complete data set for 16 of the 21 sectors of the Brazilian manufacturing industry and our time span goes from 1985 to 1997 (annual observations). The output of these 16 sectors takes in something around 92% of the total output of the manufacturing industry of the country during this period. We constructed two measures of productivity: one used "total work hours employed in production" and the other "total labor force employed in production." There is no information on value-added by industry, so that we used output as a proxy[4]. Figure 1 below presents the evolution of average productivity, average hours, average employment and average output of the 16 sectors for the entire period:



Labor Productivity (Industry Average, 1985-1997)

[4]In section 4.4 we present some evidence that this does not seem to be a problem.

In the graph above, h stands for hours, n for labor force and y for output. These 13 years can be divided into 3 sub-periods: 1985-1989, 1990-1993 and 1994-1997. In the first one, labor productivity grew very little or declined in most sectors. On average, the annual rate for the entire manufacturing sector was 0.6% in the output/labor concept or 0.9% in the output/hours concept. In this period output and employment increased, but the latter more than the former. Between 1990 and 1993, coinciding with the beginning of trade liberalization, average productivity increased at an annual rate of 5.94% (when using hours) or 5.93% (when using the employment concept). In this period the country was experiencing a recession but output reduction was more then offset by employment reduction. Finally, the 1994-1997 period is one of even faster productivity growth (above 7.4% in both concepts). Employment continued its downward trend but in this case output increased in all industries. All in all, the two productivity measures have the same trend for the entire period. Behavior by industry is similar, as can be seen from Table 3 below:

Table 3: Productivity Growth Rates

Industry	Period		
	1985-89	1990-93	1994-97
Nonmetal mineral products	0.40%	4.59%	10.26%
Metalworking	0.37%	7.11%	4.96%
Machinery	3.42%	5.68%	5.38%
Electronic and communication equipment	0.55%	8.35%	8.20%
Transportation and motor vehicles	-2.61%	9.79%	10.02%
Paper and paper products	1.33%	7.34%	5.75%
Rubber products	0.22%	3.53%	11.91%
Chemicals	0.16%	6.09%	7.72%
Pharmaceuticals	-0.80%	-0.85%	5.73%
Perfumes, soap and candles	4.36%	6.87%	2.62%
Plastic products	0.17%	3.08%	12.70%
Textiles	-3.64%	7.93%	5.41%
Clothing, fabric products and footwear	-0.54%	5.12%	7.48%
Food	-2.37%	5.82%	6.70%
Beverages	4.54%	7.09%	6.03%
Tobacco	4.37%	7.41%	7.71%
average	0.62%	5.93%	7.41%

In the 1994-1997 period, all the 16 sectors experienced fast productivity growth, with the "plastic material" (12.7% annual growth rate) and "rubber products" (11.91% annual growth rate) industries leading. On the other hand, in the first sub-period all but 5 industries experienced annual productivity growth rates below 1% and 5 of them experienced negative growth, textiles having the worst record (-3.64% annual growth). If a different initial sub-period had been taken, 1985-1990 instead of 1985-1989, we would observe that 10 industries had negative productivity growth.

It is important to note also that the relatively good performance in the second sub-period (only one industry experienced negative productivity growth) is mostly due to the growth acceleration between 1992 and 1993. Average productivity in 1992 is only 3.5% higher than in 1990, but when comparing 1990 to 1993 the difference jumps to 14%.

Is important to notice that this choice of years is somewhat arbitrary. If we compare the 85-90 period to the 91-97 period, the difference is even larger: average productivity across sectors decreased at an annual rate of -0.45% in the first period and grew at 7.1% in the second. In five of the 16 sectors output per worker grew at an annual rate above 8.3% and in only one at less than five per cent.

3.2 Total Factor Productivity

Total factor productivity is measured in the standard way. Assume a Cobb-Douglas production function:

$$Y_{it} = A_{it}.K_{it}^{\alpha}.H_{it}^{\beta}.L_{it}^{\gamma}, \quad i = 1, ..., N; \quad t = 1, ..., T, \tag{1}$$

where Y_{it} denotes output of sector i at time t, and K, H and L stand for physical capital, human capital and raw labor, respectively. Hence, in this formulation the residual A is equivalent to the TFP. Taking logarithms and differentiating with respect to time we obtain:

$$\frac{\dot{Y}_{it}}{Y_{it}} = \frac{\dot{TFP}_{it}}{TFP_{it}} + \alpha.\frac{\dot{K}_{it}}{K_{it}} + \beta.\frac{\dot{H}_{it}}{H_{it}} + \gamma.\frac{\dot{L}_{it}}{L_{it}} \tag{2}$$

Physical capital was constructed using the perpetual inventory method and it is corrected for the rate of utilization of sector capacity. As for human capital, there is no detailed information at the industry level, only aggregated information of average schooling years of the labor force for the two main groups, "modern" and "traditional" industries. Instead of discarding this incomplete information, we opted to perform two sets of estimations of the TFP, one without human capital:

$$\frac{\dot{Y}_{it}}{Y_{it}} = \frac{\dot{TFP}_{it}}{TFP_{it}} + \alpha.\frac{\dot{K}_{it}}{K_{it}} + \gamma.\frac{\dot{L}_{it}}{L_{it}} \tag{3}$$

and the other with human capital stock, so that we obtain exactly equation (2).

Our data consist of a panel of 16 industries for 13 years (from 1985 to 1997). There are basically two main techniques for panel estimation. One is the fixed-effects method, which is essentially an OLS regression with cross-section dummies. The other is the random-effects method in which the intercept is considered a random variable and the generalized least square method is used. According to Hsiao (1986) the former is the proper procedure when estimating regressions with a specific number of sectors of firms and the inference is restricted to the behavior of this set. On the other hand, if the study is concerned with a large number of individuals or firms, so that they could be viewed as a random sample of a larger population, the latter method is recommended. We ran the Hausmann specification test in order to decide between the two methods and the result favored the fixed-effects method, which we therefore used in all regressions[5].

After testing for endogeneity of output growth rates, and rejecting the consistency of the OLS, we estimated factor shares using instrumental methods. In the present case the method chosen was the Weighted 2 Stages Least Squares, which also corrects for cross-section heteroskedasticity. In this case, lagged variables were used as instruments. Moreover, constant returns of scale were imposed. Estimated factor shares, from regressions of equation (3), were slightly sensitive to the labor series employed. When we used hours the estimated labor share was 0.64, 0.10 points higher than when labor force was used. In any case, the values found are not far from international evidence and national accounting estimates. For our purposes these small differences are not important, as they did not change the behavior of the estimated TFP series, which is our final objective here.

In both cases, TFP growth rate has the following behavior: between 1985 and 1989 it declined in almost all industries, in certain cases at annual rates above 3%. From 1990 to 1993 this trend reverted, as we observe positive but small growth in all but one industry. The average growth rate jumps from minus 1% in the previous period to 2%. In the final period, again all but one industry (perfumes, soap and candles) had positive TFP annual

[5] Hence, we are implicitly associating TFP growth to be the industry-specific fixed effect plus the disturbance term.

growth, but the rates now are considerably higher as the average growth has more than doubled. In exactly half the sectors, annual growth rates are above 5%, an impressive performance. Note also that the evolution of labor productivity in the period is very similar, although magnitudes vary. Table 4 below displays TFP annual growth rates by industry in the 3 sub-periods for the case where hours were used as the labor variable.

Table 4: TFP Annual Growth Rates

Industry	Period		
	1985-89	1990-93	1994/97
Nonmetal mineral products	-0,49%	1,66%	5,58%
Metalworking	1,30%	2,77%	6,71%
Machinery	3,02%	2,96%	4,41%
Electronic and communication equipment	-0,31%	5,41%	5,32%
Transportation and motor vehicles	-6,53%	1,15%	5,54%
Paper and paper products	-1,84%	1,35%	4,40%
Rubber products	-1,67%	2,13%	4,60%
Chemicals	-4,57%	1,61%	8,10%
Pharmaceuticals	-0,56%	0,22%	0,36%
Perfumes, soap and candles	6,17%	4,78%	-0,54%
Plastic products	-1,71%	-2,88%	5,89%
Textiles	-1,61%	4,30%	2,67%
Clothing, fabric products and footwear	-4,48%	1,11%	1,23%
Food	-0,88%	3,21%	4,66%
Beverages	-0,52%	4,65%	6,68%
Tobacco	1,59%	0,82%	6,43%
average	-1,03%	2,00%	4,29%

note: TFP estimated by W2SLS.

4 Productivity Change and Trade Liberalization

Note that the observed increase in the growth rate of total factor productivity and labor productivity across industries in the period coincides with the reduction of protection to domestic industry. In the previous section, we saw that the average growth rate of TFP jumped from negative in the 85-89 period to more than 4% between 1994 and 1997. At the same time, average nominal tariffs in the last sub-period were less than 13% of first period tariffs and the effective protection rate was one fourth. In this section we investigate this relationship econometrically.

Following the same procedure as is Section 3.2, we performed Hausman specification tests and the results once again favored the fixed-effects method, which we therefore used in all regressions. We also ran the same diagnosis test to check for the endogeneity of trade variables. It could be the case that lower productivity sectors, being less able to compete with imports, received higher protection. We found, for all combinations of trade and labor variables, that the OLS test is consistent, so we did not use any instrumental method to test for the links between productivity growth and trade policy. We started regressing either nominal tariffs (NT) or effective protection rates (EPR) on labor productivity or TFP growth rates. We then included other variables that previous empirical or theoretical studies found relevant to explain productivity growth. In addition to testing their significance for the present case, this also served to test the robustness of our results. If the inclusion or exclusion of variables dramatically changed the magnitude, sign or significance of NT or EPR estimates, the results would be considered fragile and we would reject the link between them and productivity growth

We basically tested 3 additional variables: import ratio, export ratio and inflation. The trade ratio variables are industry-specific indices. They may be considered direct measures of openness but also, especially in the case of imports, indirect measures of technological adoption (see, for instance, Coe, Helpman and Hoffmaister(1995) and Holmes and Schmitz (1995)). Another channel of imports affecting growth would be increasing returns – as in Grossman and Helpman (1991). The negative impact of inflation on growth is well documented (e.g., Fischer(1993)). One possible channel would be the increase in uncertainty brought about by higher price volatility (Ramey and Ramey (1996)). For our regressions, 16 industry sector inflation rates were constructed from industry price indices. Export ratios may also be used to test export led growth arguments.

In what follows we present three sets of regressions, with different independent variables: labor productivity, TFP constructed without human capital and TFP with human capital. We used the following equation in all estimations:

$$\dot{Y}_{it} = \beta_i + \phi . Z_{it} + \varepsilon_{it}, \qquad i = 1, ..., 16, \quad t = 1985, ..., 1997 \tag{4}$$

where $\dot{Y}_{it}$ is the growth rate of productivity (either labor productivity or TFP), Z_{it} is a vector of independent variables that always contains one of the two openness indicators, β_i is the industry-specific fixed effect, and ε is the error term.

4.1 Labor productivity

Given the high correlation (0.95) between the two labor productivity measures constructed, we opted to present only the results of the estimations that used "labor force used in production" as the labor variable. Regression results with hours were very similar, as expected. Table 5 presents these results.

Table 5: Labor Productivity Growth Regressions

Model	Independent Variable		
	NT	ERP	M
1	−0.041 (−7.96)		
2		−0.048 (−7.18)	
3	−0.045 (−7.35)		0.001 (1.29)
4		−0.037 (−5.42)	0.033 (3.17)

Note: t-statistic in parentheses; NT: log of nominal tariffs; ERP: log of effective protection rate; M: log of industry-import ratio. 192 observations. Method: WLS

The results reported in Table 5 confirm the negative relationship between labor productivity and trade barriers. They are also robust to changes in the set of control variables. In models 2 and 4 one can see that a 30% reduction in the effective protection rate implies an increase between 1.5% and 1.2% in the growth rate of labor productivity. The inclusion of import ratio, inflation and/or export ratio (not reported here) did not change the results, although the estimated coefficients were smaller in general. Remember that in certain cases (see Table 3) effective protection dropped from more than 200% to less than 25% and that, on the average, it fell from 75% to 20%. Hence, the present results would imply, for instance, that the 70% mean reduction in effective protection rate could explain an increase of 3 to 4 points in the labor productivity growth rate. Remember also that prior to trade liberalization labor productivity was falling at an annual rate of 1% and that in the last 4 years, it increased 8% per year on average.

The results of the regressions with nominal tariffs (Models 1 and 3) are also significant and robust to changes in controls. They also show that increases in protection imply slower productivity growth and the estimated elasticities are the same order of magnitude as in Models 2 and 4. A 20% reduction in the average nominal tariff for any industry would induce increases around 1% of its productivity growth rate. We have seen that the average tariff reduction in the period was around 85%, so that, according to the estimations above, this brought a 6% increase in the productivity growth rate.

With respect to the other control variables, the impact of the inflation rate was either estimated as negligible or non-significant. This result holds also for TFP regressions. Uncertainty or own price increases do not seem to be an issue for industry productivity determination. The estimated coefficient of import ratio had the expected sign and was significant in some cases. Higher sector imports seem to be mildly correlated to increases in labor productivity. On the other hand, export ratios were not robust and not significant in almost all regressions[6].

4.2 Total Factor Productivity

Table 6 presents the results of the estimations of equation (4) with TFP growth rate as the dependent variable.

Table 6: TFP Growth Regressions(w/o Human Capital)

Model	Independent Variable		
	NT	ERP	M
1	−0.031 (−6.23)		
2		−0.040 (−6.10)	
3	−0.030 (−5.55)		2,30 (0.66)
4		−0.038 (−5.41)	1.75 (0.44)

note: t-stat. in parentheses, method:WLS

Results are similar to those obtained with labor productivity. Whether trade barriers are measured by the effective rate of protection or nominal tariffs, the estimated effect on total factor productivity growth is negative, robust to control variables and always significant. The estimated coefficients are slightly smaller, but of relevant magnitude in any event: −0.03

[6] Note that Tables 5 to7 do not present all regressions used to test robustness. The total number is much larger, as it includes not only exports but also combinations of exports, imports and inflation. The resulting estimations, however, are very similar.

in the regressions with nominal tariffs, and −0.04 in the regressions with effective rate of protection. This is somewhat to be expected, as now we are subtracting the effect of capital stock; moreover, TFP growth rates are on average considerably smaller than labor productivity growth rates. Still, trade liberalization in the country can explain a large part of TFP growth: the decrease in the effective rate of protection observed in the period implies, according to our estimations, an increase of 3% in the TFP growth rate. If we use nominal tariffs, the estimated impact is even larger, as tariff reduction is more dramatic than the drop in the effective rate of protection and the estimated elasticity is also higher in absolute value. Results for import ratio, export ratio and inflation follow exactly those of the labor productivity case. For instance, the estimate effect of inflation is not significant at the usual confidence interval.

Table 7 presents regression results of the case where TFP was constructed considering human capital.

Table 7: TFP Growth Regressions(w/ H. Capital)

Model	Independent Variable		
	NT	ERP	M
1	−0.031 (−3.38)		
2		−0.026 (−2.77)	
3	−0.029 (−2.94)		10.135 (2.64)
4		−0.021 (−2.50)	11.904 (3.15)

Note: t-stat. in parentheses. Method: WLS

They closely follow the results of the previous table. Estimates of the TFP growth elasticity with respect to the effective protection rate are smaller than corresponding estimates using nominal tariffs. According to the present results, increases of 20% in the latter variable would decrease the TFP growth rate by 0.6%, and increases of the same order of magnitude in the effective protection rate would reduce the TFP growth rate by 0.5%. These values are smaller than estimations in the previous tables, but are still robust and very significant. When we take into account the magnitude of the trade liberalization and tariff reduction in the country, the estimated effect is still very relevant. For the plastics industry, for instance, where the effective rate of protection dropped by more than 90%, the estimated increase in TFP growth rates is above 2.3%.

4.3 Output Growth Regressions

A potential restriction to the previous regressions is that when we first estimate the TFP and then the effect of trade barriers on it, the errors of the two sets of regressions might compound on each other. The final estimated elasticity, hence, might be estimated less precisely than if we just estimate a production function directly, substituting it in the trade variable. In other words, we have been assuming the following relationship between productivity growth and, for instance, nominal tariffs:

$$\frac{\dot{TFP}_{it}}{TFP_{it}} = \beta_i + \phi NT_i + \varepsilon_{it}$$

where β_i is the country-specific fixed effect and ε_{it} is the disturbance term. So we could plug the above expression in (3) and obtain:

$$\frac{\dot{Y}_{it}}{Y_{it}} = \beta_i + \phi NT_i + \alpha.\frac{\dot{K}_{it}}{K_{it}} + \gamma.\frac{\dot{L}_{it}}{L_{it}} + \varepsilon_{it} \tag{5}$$

This type of model was used, for instance, in Harrison(1995) for panel data of developing countries. In this case, the effect of trade barriers on output growth when directly controlling for factor growth is estimated. Table 8 below presents the results of the estimation of equation (5) using our panel of Brazilian industries:

After testing, we used the W2SLS method with lag variables serving as instruments for factors of production but with no instruments for the trade variables. We ran regressions using both hours and labor force as the labor variable. As can be seen from the four regressions above, the estimated effect of trade restriction measures on output growth is significant and has the expected sign in all regressions. Moreover, the estimated coefficients are considerably higher, in the case of nominal tariffs being more than twice as big as those in Table 6. In Model 2, for instance, it is -0.063, whereas in Table 6 it is at most -0.031. The sequential estimation (first the TFP, then trade barriers on TFP), if anything, hurts the case of negative growth effects of trade barriers, as it can be acting as a downward bias.

Table 8: Output Growth Regressions

Model	Independent Variable				
	Dk	Dn	Dh	ERP	NT
1	0.47	0.53		−0.067	
	(6.94)	-		(−6.98)	
2	0.50	0.50			−0.063
	(6.50)	-			(−7.74)
3	0.43		0.57	−0.063	
	(6.36)		-	(−6.49)	
4	0.47		0.53		−0.060
	(6.16)		-		(−7.62)

Note: t-statistic in parentheses. Dk, Dn and Dh: growth rate of physical capital, labor force and hours, respectively.

4.4 Alternative Frameworks

One potential caveat to our results is that output is used as a proxy for value-added in the regressions that construct the industry specific TFP growth. Similarly, labor productivity measure does not control for the change in intermediate input. So, given that the value of nominal tariffs and effective protection rates are negatively correlated to imports, the estimated trade reform effect on productivity may have captured the effect of trade reform on the increasing imported materials into the production of the industries.

There are no value-added data collected in any survey, but there is a (poor) proxy, value of industrial transformation (VIT), obtained in the Annual Industry Survey (“Pesquisa Industrial Anual”) of the IBGE (”Brazilian Bureau of Geography and Statistics”). It subtracts from gross output the value of most materials and services used. There are some serious methodological problems with this series and, in general, data obtained from the annual survey is not as trustworthy as the monthly survey data used in this paper. Nonetheless, we could gain some insights from the study of the behavior of the VIT series.

The first point worth noting is that the ratio of VIT to output is relatively stable, decreasing slightly from 56% to 51% over the whole interval 1988 and 1995, after reaching 60% in 1992. Hence, the growth rate of output is not a bad proxy for the growth rate of value added. Second, we constructed new measures of TFP using data from the annual survey (at a different aggregation level, now closer to the 4-digit classification) and repeated the estimations of Table 6 with the corresponding values of nominal tariffs and effective protection rate[7]. In the model that used nominal tariff the estimated coefficient was only significant at 9%, but in the case of effective protection rate results were very similar to those in the previous sections, the estimated coefficient significant at the usual levels and close to -0.10. Hence, we have indications that the estimated trade reform effect on productivity stands for changes in the value-added proxy and the use of output does not seem to be a problem.

Finally, one may also object to the assumptions of constant returns to scale technology and perfectly competitive goods and input markets used in the construction of TFP. Moreover, trade reform is likely to alter the competitive environment, but we assumed perfect competition before and after liberalization. We follow Harrison(1994) in using a procedure based on Hall(1988) and tested, jointly, perfect competition and market structure stability, as measured by changes in (estimated) price-cost margins. However, results are slightly sensitive to the factor shares used in the test and if conveniently picked one could impose any result[8]. We could not use the shares estimated in Section 3.2 as they were obtained under the hypothesis of perfect competition, so in order to avoid arbitrary choices we tested different values.

For the case where labor share was assumed to be 0.65, we could not reject the null of perfect competition in a majority of industries (11 out of 16). Moreover, there was no evidence, for any industry, of (statistically significant) changes in mark-ups after liberalization. For the five industries where perfect competition was rejected, labor to capital ratio increased or had no trend before trade liberalization and then decreased after it. According to Harrison´s (1994) Figure 1, this fact combined with price to cost margins greater than one implies in under-estimation of productivity gains after trade reform. Hence, the perfect competition assumption in these five cases, if anything, is hurting the case of trade liberalization affecting productivity growth[9].

[7] The fixed-effect method was used after testing. The data set consists of 45 industries and 7 time-series observations. We did not include human capital for lack of data.

[8] This was not a problem in Harrison´s paper because it had information of the value of the observed share for each plant in every year of the study.

[9] We also ran a series of regressions with 3-year averages, in order to reduce potential problems caused by business fluctuations. Results did not changed much: the estimated coefficients of the effective rate of protection and nominal tariffs on TFP growth regressions were almost the same as in those displayed in Tables 6 and 7.

5 Concluding Remarks

All the estimated measures of productivity growth for the industries studied in this article display a common pattern of behavior in the years between 1985 and 1997: they fall or stagnate until 1990 and then increase remarkably after that. In the same period, the country moved to liberalize its international trade, reducing tariffs, eliminating import quotas and reserved market shares and consequently decreasing the protection of domestic production.

Results in this article allow us to conclude that there is a significant and robust relation between these two facts, so that trade reform had an important impact on industrial performance. In the cross-sectional dimension, the estimations imply that the higher the protection the lower the growth rate of TFP and labor productivity of a given industry. These results are robust to changes in the data used, in the controls and in the methodology and do not depend on any restrictive assumption.

The framework used here had some advantages with respect to most of the existing literature. First, our sample years comprise data before and after (and during) trade reform, providing a flavor of natural experiment to the analysis. Second, this large time span also allows sufficient variation in the data. Third, our study centers on a single country, avoiding institutional and country-specific factors that are difficult to control. Finally, Brazil is a relatively large economy and until the nineties was one of the most closed country in the world, increasing the prospective gains from trade. Moreover, Latin America and most of the developing world adopted similar policy patterns (i.e., import substitution followed by trade liberalization) so that results in this study may hint at on a comparable relationship between trade reform and productivity gains throughout these countries.

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A Data

- Labor and Output: Labor productivity and output series were constructed using information obtained in the "Pesquisas Industrial Mensal - Produção Física" (Monthly Industry Survey - Physical Production) and "Pesquisas Industrial Mensal-Dados Gerais" (Monthly Industry Survey - General Data), both from IBGE, the public statistics bureau of Brazil. We constructed two measures of productivity: one used "total work hours employed in production" and the other "total labor force employed in production.". These series do not include administrative workers and services such as security or cleaning, so that the corresponding productivity measure is not affected by the observed trend of sub-contracting some of these services.

- Physical Capital: The capital series was constructed from investment data obtained in the "Pesquisa Industrial Anual ("Annual Industry Survey") of the IBGE. We used the perpetual inventory method, assuming a constant annual depreciation rate of 5% per year, and investment values were deflated by the gross capital deflator calculated in the national account. In order to remove possible effects of business cycle fluctuations on TFP, the stock of capital obtained was multiplied by the rate of utilization of sector capacity to obtain the fraction of physical capital effectively used in production.

- Human Capital: As for human capital, there is no detailed information at the industry level, only aggregated information of average schooling years of the labor force for the two main groups, "modern" and "traditional" industries, surveyed by the IBGE. The first group includes the following sectors: transportation equipment, electronic and communication equipment, mechanical machinery, plastic products and metalworking, the remaining sectors being classified as traditional. Consequently, most of the variation is in the time-series dimension, given that for each year there are only two observations of the human capital stock.

- Effective Protection Rate: this variable was constructed using the following formula:

$$g_j = (t_j - \sum a_{ij}^{lc}.t_i)/(1 - \sum a_{ij}^{lc})$$

where $a_{ij}^{lc} = a_{ij}^{d}.(1 + t_j)/(1 + t_i)$ is the free trade technical coefficient, measuring input i participation in final price of industry j (both at international prices); a_{ij}^{d} is the distortionary technical coefficient, measuring input i participation in final price of industry j, at domestic prices; t_j is the nominal tariff in industry j and t_i is the nominal tariff of input i.